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THE EFFECT OF CLAY AND LOAM ON THE STRENGTH OF PORTLAND CEMENT MORTARS.

By W. C. HOAD, University of Kansas, Lawrence.

Read before the Academy, at Topeka, December 30, 1904.

IN constructive engineering, the use of cement mortar, both as a binding material for stone and brick masonry and as a matrix for concrete, is increasing every year by enormous strides. This cement mortar, made of hydraulic cement, sand, and water, is very much stronger, more convenient to handle and can be used in many more ways than the old lime mortar, whose place it has largely taken. It is also more costly. On account of both this greater cost and the greatly enlarged field of usefulness of cement mortar, the quality of the sand used in its manufacture is of greatly increased importance.

Frequently, on work involving concrete or masonry construction, dirty sand—that is, sand with a small admixture of clay or fine silt—is the only kind practically available, and the question as to whether such sand may be properly used as it is, or whether it must be washed before being used, is often a very troublesome one to the inspector in charge of the work, as well as to the engineer who draws up the specifications.

Under circumstances of this kind, there naturally arises the question, How much does this dirt in the sand detract from the strength of the resulting mortar? and until recently reliable data on this point were almost entirely lacking. There has been, it is true, a feeling among the users of mortar that perfectly clean sand was the best for this purpose, and that any adulterant, like dust or dirt, was injurious. Indeed, the idea has become so firmly rooted that the specification that "the sand used on this work shall be clean, sharp and coarse" has almost hardened into a formula. But, as the thorough washing of dirty sand is an expensive operation, the cost of structures where this specification is enforced is obviously increased, sometimes by a rather large percentage of the total cost.

Largely owing to the greatly increased use of concrete in engineering structures and the correspondingly increased importance of a thorough knowledge of the effect of dirt in the sand upon the strength of the mortar, an investigation into the subject was undertaken last winter, as a graduation thesis in the department of civil engineering at the University of Kansas, by Messrs. Ben. C. Hoefer and Earle Nelson. This investigation consisted for the most part of a series of tests of the tensile strength of mortar made of Portland cement and sand containing various proportions, from two to twenty per cent., of clay or loam.

The cement experimented with was the Iola brand of Portland cement, a cement much used in engineering construction in this part of the country. The sand used was the standard Ottawa sand adopted for cement testing by the American Society of Civil Engineers. The clay was the ordinary reddish clay commonly found on the hillsides west of the University campus and the loam was from the top soil of a corn-field.

In making the mortar briquettes for testing, the proportion of one part of cement to three parts of sand was used. When clay or loam was added, it was taken as a certain percentage of the sand, and thus the ratio of cement to sand, or of cement to clay or loam and sand, was maintained constant. All proportions were by weight.

At the end of three, seven, twenty-eight and ninety days sets of briquettes of the various proportions of clay and loam were broken in a late model Falkenau-Sinclair automatic cement-testing machine. The results for the clay mixtures are given in table 1 and shown graphically in diagram 1, while those for the loam mixtures are shown in table 2 and diagram 2. Each set consisted of six briquettes, the mean of the three strongest briquettes in each set being taken. Each number in the tables and each point in the diagrams represents one set. The small discrepancy between the results in the two columns headed "0 %" in the two tables is due to slight differences in manipulation by the two operators.

TABLE 1.—Showing strength of mortar with clay added.

Age, in days.	Percentage of clay.						
	0%	2%	4%	6%	10%	15%	20%
3..........	218	193	192	192	212	147	198
7..........	325	387	392	380	353	297	232
28..........	398	502	560	518	508	448	397
90..........	512	552	637	638	577	540	490

TABLE 2.—Showing strength of mortar with loam added.

Age, in days.	Percentage of loam.						
	0%	2%	4%	6%	10%	15%	20%
3..........	207	150	248	187	162	120	125
7..........	352	333	347	352	312	200	188
28..........	470	467	553	482	490	435	372
90..........	518	542	597	615	507	477	485

These tests indicate clearly that the presence of clay or loam in the small amounts usually found in dirty sand (say from two to ten per cent.) does not detract from the strength of the mortar, but rather

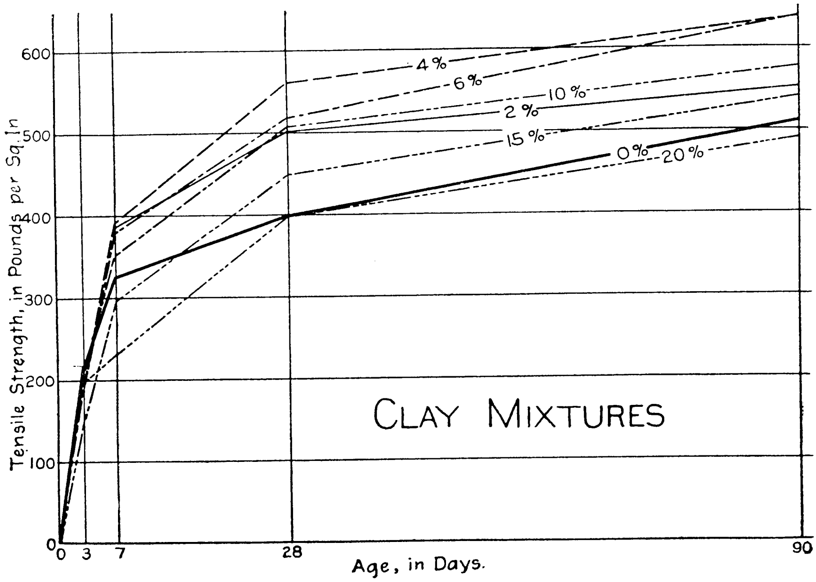

FIG. 1. Diagram showing tensile strength of mortar with clay added.

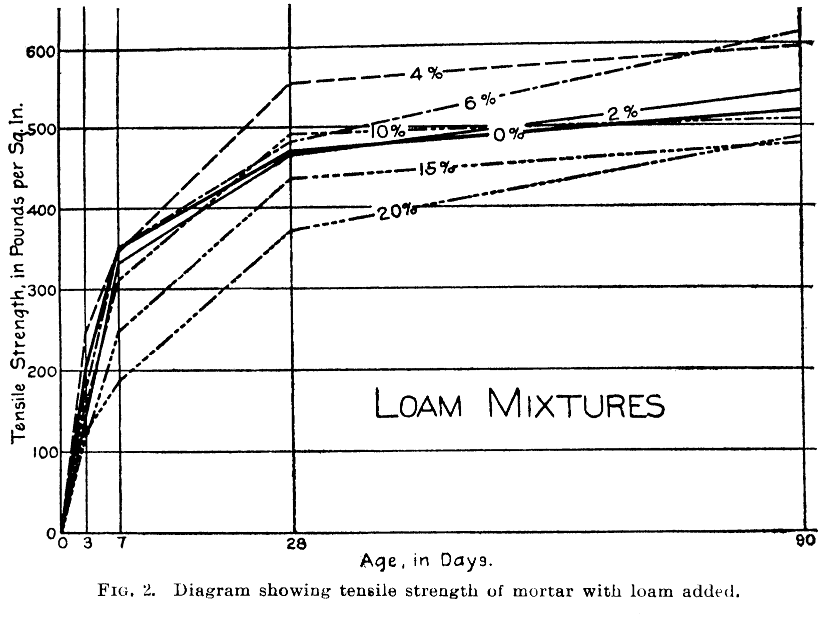

FIG. 2. Diagram showing tensile strength of mortar with loam added.

adds to it. There seems to be no important difference between the effect of clay and that of loam. It is also apparent from the diagrams that short-time tests of this nature are not of much value.

Table 3 gives the amounts of water absorbed by the briquettes in twenty-four hours, stated as percentages of the dry weights. These results, while not conclusive, point to the inference that one-to-three mortars made with sand containing up to five or six per cent. of clay or loam are at least as dense as those made with clean sand. With leaner mortars—that is, those with a smaller proportion of cement—the greater density of the dirty mortars would doubtless be more apparent. It will be noted that the effect of clay in increasing the density of mortar is noticeably greater than that of loam. This is doubtless due to the exceedingly small size of the clay grains, enabling them to fill the interstitial spaces of the cement.

TABLE 3.—Showing absorption of mortars with clay and loam added.

Per cent. of clay or loam.	Per cent. of water absorbed in twenty-four hours.	
	Clay.	Loam.
0	5.5	4.5
2	4.0	4.3
4	3.9	4.4
6	4.8	4.6
10	4.9	7.4
15	6.1	7.0
20	6.6	6.7

Some other experimental evidence bearing out the conclusions just stated may be briefly noted.

A number of years ago, Mr. E. C. Clark, of Boston, concluded, from tests* made with Rosendale cement, that an admixture of a small amount of loam or clay did not weaken mortar after six months or a year. His experiments were continued in part over two and one-half years.

About two years ago a series of tests was carried out at the Ohio State University† along the same line. These tests were quite similar in their nature to those just described, but were much more extended. Two Portland cements and three kinds of sand were experimented with, and the tests covered the period of a year. The results of these tests pointed strongly to the conclusion that the effect of clay or loam in sand, up to about fifteen per cent., was to increase rather than to decrease the tensile strength of the mortar. This investigation, so far as the writer knows, is the most extended that has been made on this subject.

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* Trans. Am. Soc. of Civil Engineers, vol. 14, p. 163.

† *Engineering News*, vol. 50, p. 443.

In view of the data above presented or referred to, it would seem to be a waste of money to require small amounts of earthy material to be washed out of sand that is to be used for Portland cement mortar, whether that mortar is to be used in ordinary masonry or in concrete. An exception to this conclusion might be taken if the mortar were to be placed under water, or if a quick-setting mortar were desired, but experimental evidence on these points is still lacking. For the general uses of cement mortar, the conclusions stated above would hold good.